SOME ASPECTS OF CHEMICAL TREATMENT AT ST. LOUIS WATER WORKS[1]

By A. V. Graf

The principal streams contributing to the water supply of the city of St. Louis are the Mississippi, Illinois and Missouri Rivers. The Illinois River enters the Mississippi 33 miles north of the intakes at the Chain of Rocks and in traversing this distance a more or less intimate mixture of the two waters is effected. The Missouri River enters the Mississippi 5½ miles north of the intakes and causes a pressing of the Mississippi River water upon the east bank of the river and in this way, as a rule, very little mixing of the two waters occurs by the time the water reaches the intakes. At times the turbidity of the water on the west side of the river is ten times as great as that of the water on the east side, and at other times the color of the east water is 25 parts per million greater than that of the west water, showing the incompleteness of the mixing of the two waters. With a high stage in either river and a low stage in the other, the mixing of the waters is more complete.

The waters in each of these rivers have certain characteristics which become of greater or less interest as the stages of the rivers vary. The Mississippi River drainage area being covered with swamps, the water in this river becomes highly colored at times of heavy run-off, while the Illinois River, carrying a large amount of sewage, contains colloidal organic matter which seems to act as a protective colloid on the turbidity carried by this river. The water in the Missouri River, always turbid, becomes much more so at times of heavy run-off. The dissolved solids in these waters vary considerably but dissolved solids offer no difficulty in the treatment of the water and are therefore of less interest.

The river water enters the plant through two intakes, one, the old or west intake, 1500 feet east of the west bank of the river and connected to the wet well by a 7-foot circular, brick-lined tunnel, 2197 feet long. The other, or east intake, is 700 feet east and 200

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feet north of the west intake and is connected to the wet well by an 8-foot circular, concrete-lined, tunnel 2747 feet long.

The water drawn through the west intake is principally Missouri River water for the greater part of the year, while the water drawn through the east intake is that of the mixture of the Mississippi and Illinois River waters, although at times the water at both intakes is practically the same both chemically and physically.

The east intake was in service only ninety-seven days during the past year whereas the west intake was used for three hundred and fifty days. Because of the greater difficulty of treating the water from the east intake, this is not used unless low stages of the river or anchor ice, or both, are affecting the pumping.

The water entering the tunnels flows by gravity to the wet well, whence it is pumped, against a dynamic head of 58.3 feet, into the delivery well and flows from there to the grit chamber where the average velocity of flow, at a rate of pumping of 150,000,000 gallons per day, is only 0.33 foot per second. In this chamber the coarser and heavier part of the suspended matter is deposited, the amount removed depending upon the character of the suspended matter as well as upon the amount present in the water. The efficiency of the grit chamber is shown in the fineness of the material removed, over 50 per cent of the matter deposited passing a 100-mesh sieve. The tons of matter removed by the grit chamber during the past year was 63,703 or 23 per cent of the total suspended matter present in the water.

Leaving the grit chamber, the water flows through a short conduit to the mixing chamber, where milk of lime and a solution of sulphate of iron are added. These chemicals are prepared in the coagulant house for addition to the water and are pumped a distance of 900 feet to the mixing chamber.

The lime is weighed out in automatic scales and is dumped into circular slaking tanks which are provided with revolving rakes. The temperature of the milk of lime in the slaking tank is kept at 200°F. This is accomplished by keeping up the temperature of the fresh water supply by passing it through the coils of a heater tank into which the milk of lime at 200° is drawn. From 4 to 4½ pounds of water per pound of lime are used in slaking. The water overflowing from the water tank is run into a cooling and diluting box, where the temperature is reduced to as low as 64° in winter time to 108° in summer. The strength of the milk of lime as pumped is 38,600 parts per million of CaO.

A slaker tank is kept in service until the accumulated unslakeable material is great enough to impede the motion of the rakes. From 50 to 150 tons of lime are slaked before a tank is taken out of service, the amount depending upon the purity of the lime. Tests made to determine the effect of limes of varying percentages of CaO upon the amount of lime that could be slaked before a slaking tank had to be taken out of service, showed that for every increase of 1 per cent in the available CaO, above the lowest lime tested, an additional 10 tons could be slaked. Contracts for lime are let under a specification requiring a lime of 85 per cent CaO, with a bonus or penalty of 1.5 per cent for each 1 per cent above or below the required 85 per cent.

The sulphate of iron is measured by passing it through an adjustable orifice onto the surface of a cylindrical drum, revolving at a constant speed and is discharged in a continuous flow into a tank, where it is dissolved without stirring, by water entering through a manifold at the bottom of the tank, the solution being drawn off through an overflow.

The mixing conduit into which the chemicals are delivered is a reinforced concrete box, 2382 feet long, 32 feet 1 inch wide and 12 feet 6 inches high, divided longitudinally into four compartments, each 7 feet wide and 11 feet high. The four compartments are supplied with stop-plank openings so that they may be thrown in parallel, used in series or withdrawn from service for cleaning. In normal operation the water enters the west channel and travels the full length four times, a total of 9528 feet, having an average velocity of 3.3 feet per second when the rate of pumping is 150,000,000 gallons a day.

Provision is made so that the lime or iron may be added to either of the four compartments, but the lime is added, for the greater part of the time, to the raw water as it enters the mixing conduit and the sulphate of iron as it leaves the conduit. The period of mixing averages about one hour. The sides and bottoms of the first two compartments are badly coated; the coating on the sides is practically all calcium and magnesium carbonates and magnesium hydroxide while the bottom coating consists of the sand and unslakeable material present in the lime added, bound together by the precipitated calcium carbonate and magnesium hydroxide.

The value of the mixing chamber is shown by an occurrence of last year. A leak in the south end of the mixing conduit, due to the failure of the contractor to properly plug a drain, caused the conduit

to be taken out of service. The water was passed from the delivery well direct to the first of the sedimentation basins, the sulphate of iron being added in the tunnel at the coagulant house and the milk of lime at the delivery well.

The turbidity of the water in the delivery well was 2500 at the time and the turbidity of the water in the last of the sedimentation basins was 20, the amounts of chemicals added being 6.25 grains of lime per gallon and 0.25 grain of sulphate of iron. After the mixing conduit was taken out of service, the sulphate of iron was increased to 2.50 grains per gallon, the lime remaining the same. In forty hours the turbidity of the water, in the last of the sedimentation basins, increased to 40, the turbidity of the river water remaining practically the same as on the preceding days. By adding ten times the amount of sulphate, the results were still inferior to what was accomplished with the mixing conduit in use. The additional cost due to the use of a larger amount of sulphate of iron while the conduit was out of service, one and one-half days, was $390.

The points of application of the milk of lime and sulphate of iron depend upon the condition of the raw water. With a water high in color and low in turbidity the iron is added before the lime with good results. If the high color is accompanied by a turbidity of 200 to 300 parts per million, better results are obtained by adding the sulphate of iron as the water leaves the mixing conduit. With high turbidity the lime is always added at the first opening and the sulphate of iron at the last. With low color and low turbidity due to colloidal matter, the sulphate of iron is added at the third opening, which allows a mixing through one-half of the conduit. At times with finely divided suspended matter in the raw water, the only sedimentation that takes place is accomplished in the first basin, the turbidity of the water in the last of the sedimentation basins being as great as that of the water leaving the first basin.

With high stages in the Mississippi and Illinois Rivers and a low stage in the Missouri, the worst condition is encountered. The high color of the Mississippi together with the colloidal matter in the Illinois make a water hard to handle. The use of sulphate of iron, as a coagulant, at these times is accompanied by some difficulty. The coloring matter of the water combines with the iron and instead of a diminution in color, the color is increased. The suspended matter being really colloidal and some of the iron hydroxide remaining in the colloidal condition, the turbidity of the water after sedimentation is

greater than that of the river. This highly colored and turbid water is much less amenable to treatment with sulphate of alumina. The amount of sulphate of alumina required to give the required flocculation of the suspended matter is from 4 to 5 grains per gallon. With this large amount of sulphate, the water passing the filters is clear but is still of high color, the iron content being eight to ten times as great as normally. At times when this condition occurs, no relief is experienced until the Missouri River run-off increases and thereby gives a turbid water which offers enough suspended matter for the rapid subsidence of the floc of ferric hydroxide. The more turbid the water at the intakes, the less trouble there is with turbidity causing material remaining in suspension.

After passing through the mixing conduit, the water enters the first of six sedimentation basins, each 400 feet long by 670 feet wide, of 30,000,000 gallons capacity. The first three division walls have five stop-plank openings and the last two four openings, all 4½ feet deep by 8 feet long. These openings render the sedimentation basins less efficient than would wiers extending the full width of the basins, but because of the necessity of maintaining an elevation of the water but little lower then the top of the basins, the need of stop-plank openings at times of cleaning is apparent. The time of sedimentation, based upon the capacity of the basins, varies from thirty to forty-three hours, but the actual time is much less, the effects of a change in the amounts of chemicals added being noticeable in twelve to fifteen hours in the last of the basins. About 90 per cent of the suspended matter and bacteria are removed in the first basin and 9 per cent in the remaining basins.

The total amount of matter removed from the water during the past year, including the chemicals added and the dissolved solids removed, amounted to 326,775 tons or 484,111 cubic yards. Some of the mud was removed by opening the sewer gate for one-half hour at varying intervals but the greater part was removed from the basins by labor and teams. The teams are used to draw scrapers which cut off portions of the mass of mud and drag them to the central gutter, through which water is flowing. The men are provided with scrapers which are used as such and also as braces to keep small A-shaped boxes in place, as the mud drawn by the horses and the water used to aid in removing the mud are drawn by the boxes. The cost of the removal of the mud from the sedimentation basins, not including the cost of the water, was 0.762 cent per cubic yard for the past year.

The water leaving the sedimentation basins enters a collecting conduit and passes through two 8-foot Venturi meters and into a small secondary coagulation basin, connected to secondary sedimentation basins by stop-plank openings. The solution of sulphate of alumina is added at the throat of the meters and is automatically controlled so that the quantity added per unit is constant for any setting, regardless of fluctuations in the flow through the meters.

No mixing chamber is provided here because of the low permissible loss of head, namely, $1\frac{1}{2}$ feet. There are two secondary sedimentation basins, one east of the filter plant and one north, each of which is connected to the influent flume of the filters. The time of reaction and sedimentation, based on capacity, is twelve hours with both basins in service and six hours with one. The water entering the secondary coagulation basins being usually of a turbidity less than 20, little sedimentation takes place. It is not expected that these basins will need cleaning for some years.

The water entering the filter plant is passed through 40 filters, each with a filtering area of 1400 square feet, of 4,000,000 gallons capacity. The filtering media consist of 30 inches of sand above 12 inches of graded gravel. The effective size of the filter sand as placed in the filters was 0.341 mm., with a uniformity coefficient of 1.81. The effective size has increased to 0.407 mm. and the uniformity coefficient has been reduced to 1.45 due to the coating of the sand grains by material having the following composition:

	per cent
$CaCO_3$	76.00
$Al_2(OH)_3$ and $Fe(OH)_3$	15.00
$Mg(OH)_2$	9.00

Liquid chlorine, in the form of chlorine water, is added after filtration in a chamber in which the filtered water from the three connections to the effluent flume is combined. Two conduits, one a 7-foot $\frac{1}{2}$-inch steel tube, the other a brick and masonry conduit 9 feet high and 11 feet wide, are connected to this chamber. These conduits convey the water to the pumping stations at Bissell's Point and Baden. The bacterial reductions caused by the chlorine were far from satisfactory until a baffle was built in the chamber to aid in mixing the chlorine with the water.

The reduction in bacteria in the water flowing through the steel line is always less than in the water in the brick conduit. Charges

of chlorine great enough to give tests for free chlorine in the water in the brick conduit, three hours after treatment, give no test in the steel line three minutes after. The disappearance and ineffectiveness of the chlorine in the water entering the steel line is attributed to the steel of the line. The Electro Bleaching Gas Company supplies the liquid chlorine which is measured and controlled by the liquid type meter apparatus also supplied by this company.

The accompanying operation record for the year ending February 28, 1918, shows very clearly the kind of water treated, the improvement in the condition of the water for each step of the purification system, the amounts of chemicals used and other details of operation.

Cost of operations per million gallons, St. Louis

	1918	1917
Old purification plant:		
Lime	$2.79	$1.89
Iron	0.55	0.61
Operating and miscellaneous expenses	1.18	1.04
	$4.52	$3.54
New purification plant:		
Aluminum sulphate	$1.16	$0.79
Chlorine	0.27	0.14
Operating and miscellaneous expenses	1.32	1.12
	$2.75	$2.05
Total cost for purification	$7.27	$5.59

Pumping

	1918	1917
Chain of rocks	$3.20	$2.437
Baden	8.984	7.134
Bissell's Point	6.825	5.308

Operation Record for Year Ending Frbruary 28, 1918

Chain of Rocks filters

		Basins out of service	Days out of service	Remarks
Water pumped (Chain of Rocks) in million gallons	39,289.23			
Water consumed in million gallons	38,024.64	No. 1	24	Basins cleaned:
Water filtered	39,351.70	No. 2	24	No. 1 May, July, November, mud 128 inches
Water used in filter house operation	805.22	No. 5	11	No. 2, May, July, mud 87 inches.
Water used in coagulant house operation	97.95	No. 6	14	No. 6, November, mud 45 inches
Water used in basin operation (filtered)	278.49	No. 8	123	No. 9, August, mud 46 inches.
Water used in basin operation (unfiltered)	593.04	No. 9	9	
Water used in purification. Total	1,774.70			

Chemicals used

Description	Pounds	Grains per gallon		
		Maximum	Minimum	Average
Lime	30,147,933	8.00	4.00	5.371
Sulphate of iron	4,294,689	2.50	0.00	0.765
Sulphate of alumina (meters)	3,781,163	3.68	0.11	0.673
Sulphate of alumina (influent)	29,560	0.25	0.00	0.005
Sulphate of alumina (filters)	108,756	14 pounds per wash	0 pounds per wash	0.019 grains per gallon
Chlorine	74,516	4 pounds per million gallons	0 pounds per million gallons	1.89 pounds per million gallons

Variations in water

Description	River water			Settled water			Applied water			Water to HS. pumps		
	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.	Max.	Min.	Av.
Stage of river	105	74.9	78.4									
Temperature	84	32	54									
Turbidity, parts per million	5,000	8	1,240	110	9	24	32	4	10	0	0	0
Color, parts per million	48	10	22	35	6	14	32	5	12	28	4	9
Suspended solids, parts per million	6,930	6	1,700							0	0	0
Dissolved solids, parts per million	468	190	310							370	150	215
Total solids, parts per million	7,210	400	2,010							370	150	215
Alkalinity total, parts per million	233	93	145	146	32	60	136	27	56	127	26	53
Alkalinity caustic, parts per million				8								
Alkalinity bicarbonate, parts per million	233	93	145	122		20	120	0	28	115	8	29
Hardness total, parts per million	304	116	193							188	66	108
Bacteria gelatine, per cubic centimeter	625,000	600	55,500	7,000	59	1.020	4.800	53	710	530	2	98
Bacteria agar, per cubic centimeter	27,000	110	7,300	450	15	97	290	9	57	57	2	11
Coli, per cubic centimeter	80	0.2	17.2			0.259			0.271			0.0106

Number filters in service............ 40	Run of filter in hours:	Bacteria agar effluent.......... 16
Number filtering hours.............343,743	Max. 206.75; Min. 6.92; Av. 50.2	Bacteria gelatine effluent...... 185
Average rate filtration, million grains daily........................... 85.39	Run of filter in million gallons: Max. 22.63; min. 0.876; Av. 5.67	
Rate of wash, gallons per million.... 21,000	B. coli per cubic centimeter in effluent...................... 0.0485	
Number of washes.................. 8.931	B. coli per cubic centimeter tap water average................ 0.0121	
Per cent wash water used........... 1.56	Bacteria agar. Tap water average.. 10	
Average gallons used per wash........ 78.990		